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THE CANTWELL FORMATION: A CONTINENTAL DEPOSIT OF TERTIARY AGE IN THE ALASKA RANGE[1]

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Introductory statement.—The Cantwell formation comprises a series of conglomerates and finer clastic sediments of important though restricted development within the Alaska Range. These rocks form a belt from 3 to 23 miles in width, which has its beginning near the northeast base of Mount McKinley and extends thence eastward for at least 100 miles to Cathedral Mountain at the head of Susitna River. Its members attain their most typical and maximum expression adjacent to the Nenana Valley, intermediate between those two points.

Historical.—In 1898, during a hasty exploratory trip into the Alaska Range, Elridge noted a "series of conglomerates and coarse sandstones" on the Nenana (then called Cantwell) River, between two tributaries later designated as Jack River and Yanert Fork, and referred briefly to this group of rocks as the Cantwell Conglomerate.[2] Brooks and Prindle in 1902, on a geological reconnaissance of the Mount McKinley region, came across similar rocks at the foot of Muldrow Glacier[3] near Mount McKinley, and following along their northern border traced their extension eastward into the Yanert Fork basin, mapping the area as the

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[1] Published with the permission of the Director of the United States Geological Survey. The field work upon which this paper is based was done by F. H. Moffit and the writer, and the latter is indebted to Mr. Moffit for helpful suggestions in its preparation.

[2] George H. Elridge, "A Reconnaissance in the Sushitna Basin and Adjacent Territory, Alaska, in 1898"; *United States Geol. Survey Twentieth Ann. Rept.* (1898–99), Pt. 7, p. 16; also map 3.

[3] They also found a small area 75 miles southwest of that point near Mount Russell of the Alaska Range.

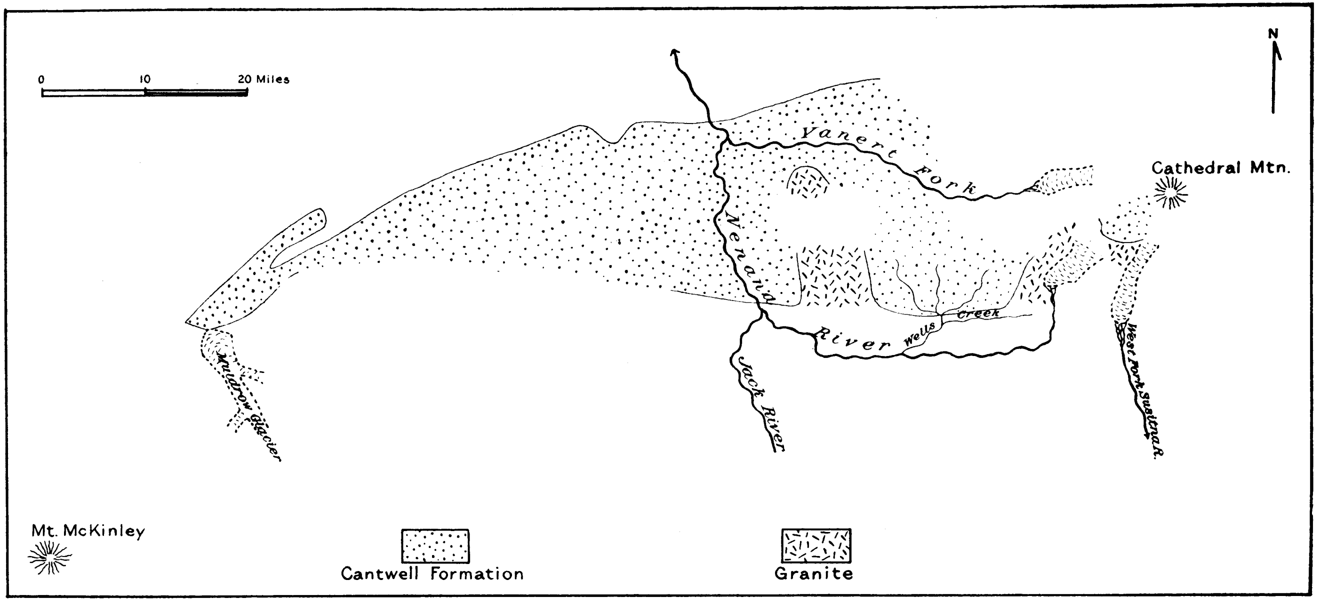

FIG. 1.—Sketch map showing the distribution of the Cantwell formation

Cantwell formation.[1] In 1913 Moffit and Pogue, during a reconnaissance survey of the Broad Pass region, encountered this belt at the mouth of Jack River and studied in some detail its eastward development up to the West Fork Glacier of Susitna River. The present paper deals primarily with this eastward extension of the Cantwell, although it is believed that the conclusions are applicable to the formation in its entirety.

Character.—In its westward extent and along its northern border, the Cantwell formation is characterized by Brooks[2] as follows:

> The Cantwell formation includes a series of heavy conglomerates interbedded with a few shale layers and succeeded by finer conglomerates and red sandstones interbedded with gray and black clay shales. . . . . The basal conglomerate of this formation is made up chiefly of well-rounded white quartz and chert pebbles, the largest of which are 2 inches in diameter. The basal character of the conglomerate is well illustrated in several localities where it rests uncomformably on the older rocks and also contains rounded fragments of them. That part of the formation seen by Elridge contained only the basal beds of the series. On being traced to the north and west these are found to be succeeded by reddish sandstone and gray, drab, and black shales. The sandstones are in some places bright red, but grade from this into a reddish-brown to medium-brown color. The shales are both argillaceous and arenaceous, the latter phase grading into a shaly sandstone. Some of them carry a large amount of carbonaceous matter, and coal seams are interbedded with these rocks, but those seen by the writer appear not to have any commercial importance. . . . .

In the area traversed by the present writer, the Cantwell formation attains its most representative development along the northward course of Nenana River below the mouth of Jack River. The stream here cuts through mountains of conglomerate, which shows in heavy massive beds up to 100 feet and more in thickness, of gentle dip and somber aspect, alternating with subordinate beds of sandstone and argillite. Eastward from the mouth of Jack River the formation changes progressively in character: The conglomerate members become less conspicuous, with increasing prominence of graywacke, sandstone, and carbonaceous shale; while the rocks no longer remain massive, but show greater and greater schistosity, the finer members passing finally into slates and phyllites, the coarser ones into mica schists.

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[1] Alfred H. Brooks, "The Mount McKinley Region, Alaska," *United States Geol. Survey, Prof. Paper 70* (1911), Plate 9.

[2] *Op. cit.*, p. 78.

The massive conglomerate was examined with especial care just east of the mouth of Jack River, where it forms prominent cliffs along the southern face of the Alaska Range. The rock is composed of grains, pebbles, and cobbles (observed up to 7 inches in length) of quartz, quartzite, slate, rhyolite porphyry (?), and perhaps other rocks, set in siliceous cement. Intercalated between these massive beds are thinner members of sandstone, quartzite, and dark-blue carbonaceous argillite. The formation is separated here from the Paleozoic limestone along its southern border by a narrow intrusion of granite, connecting eastward with a large area that intercepts the sediments for a course of several miles.

East of the granite intrusion the Cantwell formation reappears in a more accessible portion of the Alaska Range embracing the headwater region of Wells Creek. This area extends eastward for 13 miles almost to the Nenana Glacier, where it is interrupted by another great granite intrusion. The sediments show the effects of more compression than do the massive beds to the west, and in consequence display considerable schistosity. This Wells Creek area was carefully studied in its western, central, and eastern portions.

In its western portion, a good section was obtained up a small draw from the valley gravels to the mountain top. The lowermost 1,500 feet consists predominantly of massive to somewhat schistose graywackes of dark-gray color, composed of subangular to rounded pieces of quartz and black slate set in siliceous cement. This rock carries intercalated beds of black carbonaceous shales with abundant impressions of leaves and of siliceous conglomerate, in part somewhat schistose. The remaining 600 feet to the mountain top is composed of prominent, heavy beds of a severely mashed phase of the conglomerate, light greenish to yellowish in color, in places so schistose that the original texture is nearly obliterated. The average rock, however, shows the coarser components as elongated lenses, resembling so-called "stretched-pebbles," enwrapped by the finer constituents, which have been rendered in part micaceous. The beds dip northward at angles of 35° to 60°, indicating that the folding is less gentle than to the west.

In its central portion the Wells Creek development of the Cantwell was again examined in detail. The adjoined section of the lowermost portion in contact with underlying granite indicates the rapid variation in conditions that gave rise to this series.

SECTION OF LOWERMOST PORTION OF CANTWELL FORMATION NEAR WELLS CREEK

Schistose conglomerate	15 feet
Silicified tuff[1]	15 "
Alternations of schistose conglomerate and schistose graywacke, carrying beds of shattered black slate and lens-like intercalations of tuff	50 "
Dense, light-colored tuff, very hard	5 "
Fairly schistose conglomerate, grading into schistose graywacke, which in turn grades into schistose conglomerate; the whole carrying pinching and swelling lenticular beds of tuff	15 "
Graywacke, with lenses of quartzite and of shattered carbonaceous slate	30 "
Fairly massive siliceous conglomerate	2 "
Graywacke	3 "
Carbonaceous slate, badly shattered and slickensided	8 "
Graywacke, slightly schistose	15 "
Crushed slate and schistose graywacke	5 "
Graywacke, fairly massive	5 "
Covered, mostly altered graywacke	20 "
Schistose and altered graywacke, injected with quartz stringers and lenses	10 "
Granite, exposed	30 "
Glacial gravels to valley bottom.	
	228 feet

For a few hundred feet above this section the rocks are not exposed; then there appears a narrow bed of shale, bordered by a large barren quartz vein, which shows beneath a heavy somewhat contorted bed of comparatively massive conglomerate composed predominantly of white quartz pebbles averaging threefourths of an inch in diameter. From this exposure to the mountain top, a vertical distance of about 1,100 feet, the rocks are dominantly black shale with plant impressions, alternating with beds of massive graywacke, in some places approximating a sandstone. Near the eastern base of this mountain the carbonaceous, plant-bearing shales were observed to carry 2- to 2½-inch seams of impure lignitic coal. For 2½ miles north of this point mashed conglomerate alternates with dark-blue to black slate (resulting from the metamorphism of the carbonaceous shales), some phases showing a crinkly surface of satin-like luster. Many of the rocks here might properly be termed schists, and the formation as a whole presents a black aspect due to the widespread dissemination of carbonaceous material.

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[1] As shown by the microscope, this rock is composed of small pieces of quartz, with some orthoclase and a very little plagioclase—all distinctly fragmental—set in a dense, microcrystalline ground.

A traverse was carried up a stream farther eastward in the Wells Creek area. Near the southern border of the formation, this stream exposes closely folded beds of slate, graywacke, and conglomerate, all severely mashed, the conglomerate almost beyond recognition. The slate is also badly crushed and slickensides are prominently developed. For two miles above these outcrops the formation seems about equally divided between slate, graywacke, and conglomerate, the last two having suffered most from the regional metamorphism, although much of the slate has a crinkled surface, suggesting the intensity of the compression to which the rocks were subjected. Throughout this extent the rocks are steeply dipping and apparently vary from 80° N. to 80° S. In places are crinklings and plications suggestive of sharp folding, and many specimens of a peculiar, plicated phase of mashed conglomerate were observed in talus fans. The formation as a whole is dominantly dark-grayish to black in color.

East of the Wells Creek basin, the Cantwell is replaced by a large intrusion of granitic character, forming a rugged mountain range surrounding the Nenana Glacier. A few miles northeast of the glacier, at the foot of Cathedral Mountain, the Cantwell apparently appears again; this area was not directly accessible, though observable with field glass and through the agency of glacially transported specimens. The sediments here consist of dark-colored slates and mica schists, the latter representing the coarser clastics severely mashed. A typical example of the mica schist is dark-reddish to bluish-gray in color, weathering to an iron-stained surface glistening with mica scales along its planes of foliation and presenting on transverse break thin quartzose lenses, deformed survivors of original pebbles. It is only after having traced the Cantwell through its progressive stages of metamorphism from west to east that an observer would recognize this type as the mashed equivalent of the massive conglomerate so extensively developed near the mouth of Jack River, 35 miles to the west.

Associated igneous rocks.—In the western extension of the formation lava flows of andesitic, rhyolitic, and basaltic character are interbedded with the conglomerate, and these intercalations are especially prevalent toward the Nenana Valley, in some localities equaling the sediments in thickness.[1] West of the Nenana the Cantwell is cut by dikes of diabase and stocks of granite. Reference has already been made to the granite batholiths that invade the Cantwell sediments east of the Nenana Canyon. Adjacent to these areas the sediments are traversed by abundant dikes of rhyolite porphyry and diorite porphyry, the former especially conspicuous near the head of Wells Creek.

Structure.—The structure of the Cantwell formation has been suggested in the preceding paragraphs. Its low northward dip and unmetamorphosed character on the west, with increasingly steeper dips and development of schistose textures along its eastward course, point to folding, gentle to the west, more and more intense to the east. The trend of the formation, and of the axis of folding, as indicated by numerous strike measurements, as well as by the course of the southern boundary of the formation, is about N. 80° E.

The inclination of the massive conglomerate beds where the Nenana River turns northward and cuts through them indicates that the southern face of the mountains here represents the beveled upturned edge of a gentle synclinal fold. According to Brooks[2] this type of broad open folding holds for the westward extension of the formation. At the head of Wells Creek the Cantwell is structurally more complicated than in the area just noted. It here shows steep, though variable, dips, both to the north and to the south; and transverse to the trend of the sequence displays considerable variation in the degree of dynamic metamorphism, the rocks ranging from fairly massive to schistose. These observations indicate that the rocks have been subjected to considerable compression, and it is believed that the gentle folds on the west pass eastward into more intense and complicated folds, not isoclinal, but with axial planes variously inclined on an east-west axis.

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[1] Brooks, *op. cit.*, p. 79.

[2] *Op. cit.*, p. 79; also section CD on geologic map, Plate 9.

Although no faults were directly observed in the portions of the Cantwell examined, faulting was undoubtedly a resultant of the compressive forces to which the terrane has been subjected. It would appear from the increasing pressure effects to the east that the formation as a whole had suffered a differential degree of compression. Yet the possibility must not be overlooked that in the massive areas extensive faulting may have relieved the stresses that in the absence of these places of yielding would have produced close folding and schistosity there also. In the westward part of the formation (west of the Nenana), where the rocks are massive and folding gently, Brooks[1] observed a number of faults consequent upon the folding.[2]

Contact relations.—Along the northern border, according to Brooks, the Cantwell rests unconformably upon Paleozoic rocks. Along the eastern portion of the southern border, the relation to the bordering Paleozoic sediments is obscured by granite intrusions and glacial gravels, but the contact is believed to be characterized by an unconformity, although there is some evidence that the plane of separation is one of fault movement. The coming to place of the extensive granite batholiths seems to have had little structural or mineralogic effect upon the invaded sediments.

Thickness.—The thickness of the Cantwell formation was obtained with greatest accuracy in the section east of the mouth of

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[1] *Op. cit.*, pp. 79–80.

[2] Brooks (*op. cit.*, p. 79) suggests that the Cantwell is not so sharply folded as the adjacent formation, "because the massive beds were able to resist the movement, some of which has been taken up by lines of shearing that have followed the shale beds and the lines of parting between the shales and the massive beds."

Jack River, where calculations based upon aneroid and triangulation measurements show a vertical development of about 2,700 feet. In the headwater region of the Toklat basin about 25 miles to the west, Brooks[1] found that the thickness there exposed is at least 2,000 feet. These figures do not represent the total thickness of sediments as deposited, because the top of the formation is a surface of erosion, from which an uppermost portion of unknown thickness has been removed.

Age and correlation.—The Cantwell formation is assigned to the Tertiary on the basis of plant remains found in some abundance in the Wells Creek area. The following forms were identified by Drs. F. H. Knowlton and Arthur Hollick, who report that the material is of Tertiary age:

Taxodium tinajorum Heer.
Taxodium dubium (Sternberg) Heer?
Sequoia langsdorfii (Brongniart) Heer?
Populus arctica Heer?
Daphnogene Kanii Heer.
Aspidium Heerii Ettingshausen?
Ginkgo adiantoides (Unger) Heer?

In the report on the Mount McKinley region[2] the Cantwell was provisionally referred to the Carboniferous, although its lithologic resemblance to several occurrences of the Kenai formation (Eocene) was noted and the possibilities of younger age fully recognized. The extent and relation of the plant-bearing area surrounding upper Wells Creek and the fact that a locality within the western portion of the Cantwell has also furnished Tertiary plant remains showing identical species[3] would seem to fairly establish the present age assignment.[4]

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[1] *Op. cit.*, p. 81.

[2] *United States Geol. Survey, Prof. Paper* 70, 1912.

[3] Brooks, *op. cit.*, p. 82. This occurrence was interpreted as an infaulted block and the fossil evidence was not regarded as applicable to the surrounding formation.

[4] The possibility must be recognized that future detailed work may result in a subdivision of the Cantwell, as in its western portion in particular the members in which conglomerate beds dominate are succeeded by a series of shales and sandstones. It seems likely, however, that these upper members are merely an expression of normal, changing topographic conditions in the region of supply, rather than the result of a distinctly later epoch of sedimentation. In its eastern portion, where observed by the present writer, the formation appears definitely a unit.

The Cantwell as indicated by its plant remains and character is of Eocene age and corresponds in whole or in part to the Kenai formation, widely distributed in isolated areas through Alaska. This correspondence, however, should be regarded as a general one, without implication of exact time coincidence or precise analogy of formations; for the Cantwell formation and the Kenai, being throughout dominantly continental deposits, cannot be expected to display the degree of equivalence normal to marine deposits.

Origin.[1]—The character of the sediments composing the Cantwell formation signifies fluviatile continental deposition. The extensive development, number, and thickness of the conglomerate beds and the heterogeneous character of this rock indicate a source of supply under violent degradation, a short transport, and distribution by rushing waters competent to spread material of such coarseness. The presence, moreover, between the conglomerate members of carbonaceous mud rocks, carrying well-preserved plant remains in abundance and variety, implies areas of quiet deposition, such as swamps and small lakes, which alternately superseded, and in turn were transgressed by, zones of depositional activity. These conditions are afforded by voluminous streams emerging from a mountainous region on to a piedmont slope, intermontane valley, or shallow sea.

It is difficult with present information to decide whether the Cantwell was laid down as an interior continental deposit or upon the inland margin of a delta built out from a coast range of mountains. The apparent absence of deposits that might be attributed to the seaward portion of such a delta, the predominance of conglomerate over finer clastics, and topographic considerations incline the writer to favor the first explanation; although on this basis, for the preservation of the sediments from subsequent complete erosion, it must be assumed that downward warping in front of the mountain axis succeeded their deposition. That a compressive earth movement followed deposition is clearly evidenced by the present folded character of the sediments.

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[1] The interpretation of the origin of the Cantwell formation has been facilitated by a study of the contributions of Barrell on sedimentation, especially those appearing in *Jour. Geol.*, XIV (1906), 316–56, 430–57, 524–68; XVI (1908), 159–90, 255–95, 363–84; *Bull. Geol. Soc. Amer.*, XX (1909), 620; XXIII (1912), 377–46; and *Amer. Jour. Sci.*, XXXVI (1913), 429–72; XXXVII (1914), 87–109, 225–53. See also Mansfield, *Jour. Geol.*, XV (1907), 550–55.

The freshness and variety of the components of the conglomerate and finer sediments point to derivation from a region of rugged and youthful[1] topography under conditions of intense mechanical disintegration characteristic of a climate in which frost action played an important part. The presence of carbon and plant remains in the finer members of the formation indicates deposition under conditions unfavorable to oxidation, while the character of the plants themselves implies a temperate climate in the area of deposition, markedly milder than that of the region today, and in contrast also to the more rigorous conditions that prevailed in the high mountains from which the sediments were derived. The thickness and extent of the conglomerate members, moreover, seem to indicate a more vigorous precipitation than at present, capable of handling the abundant waste of the mountains. That this upland was the seat of active glaciation and consequently contributed glacial materials to the streams sweeping the Cantwell sediments downward is regarded as probable, though no observations can be adduced in support of this belief.

The presence of red sandstones toward the top, as noted by Brooks in the western portion of the formation, is not believed to have climatic significance;[2] for organic colors are conspicuous throughout that portion of the formation also. These members are rather suspected of expressing a variant in the lithology, or a change in the topography, of the source of supply.

The situation of the Tertiary land mass in reference to its basin of deposition cannot be given without reservation, but the present delineation of the Cantwell formation and the fact that its coarser members contain fragments of slate similar to that of older formations to the south and dissimilar to sediments exposed to the north suggest a position south of the present area of Tertiary rocks.

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[1] See Willis, *Jour. Geol.*, I (1893), 478.

[2] Barrell (*Jour. Geol.*, XVI [1908], 293) observes that ". . . . red shales or sandstones, as distinct from red mud and sand, may originate under intermittently rainy, subarid, or arid climate without any close relation to temperature and typically as pluvial or fluvial deposits upon the land. . . . ."